



Designing Greener Electronics: Flame Retardants in Electronics Waste

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Overview

- Design for the Environment (DfE) Program
- Flame Retardants in Printed Circuit Boards Partnership
- Hazard Assessments
 - Methodology
 - Draft Results
- End-of-Life Considerations
 - Goal
 - Testing
- Next Steps

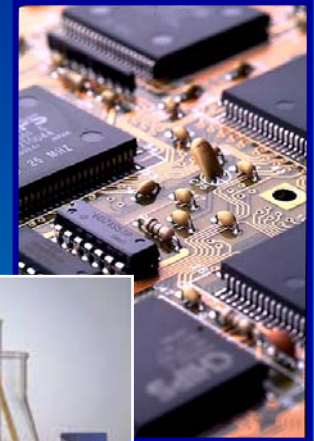
Overview of DfE Program

- Focus
 - Collaborative partnerships
 - Chemicals of concern
 - Informed Substitution
- Approach
 - OPPT technical tools and expertise
 - Business client as driver
 - Multi-stakeholder participation
- Considerations
 - Business realities
 - Potential benefits for industry and the environment



DfE Partnerships

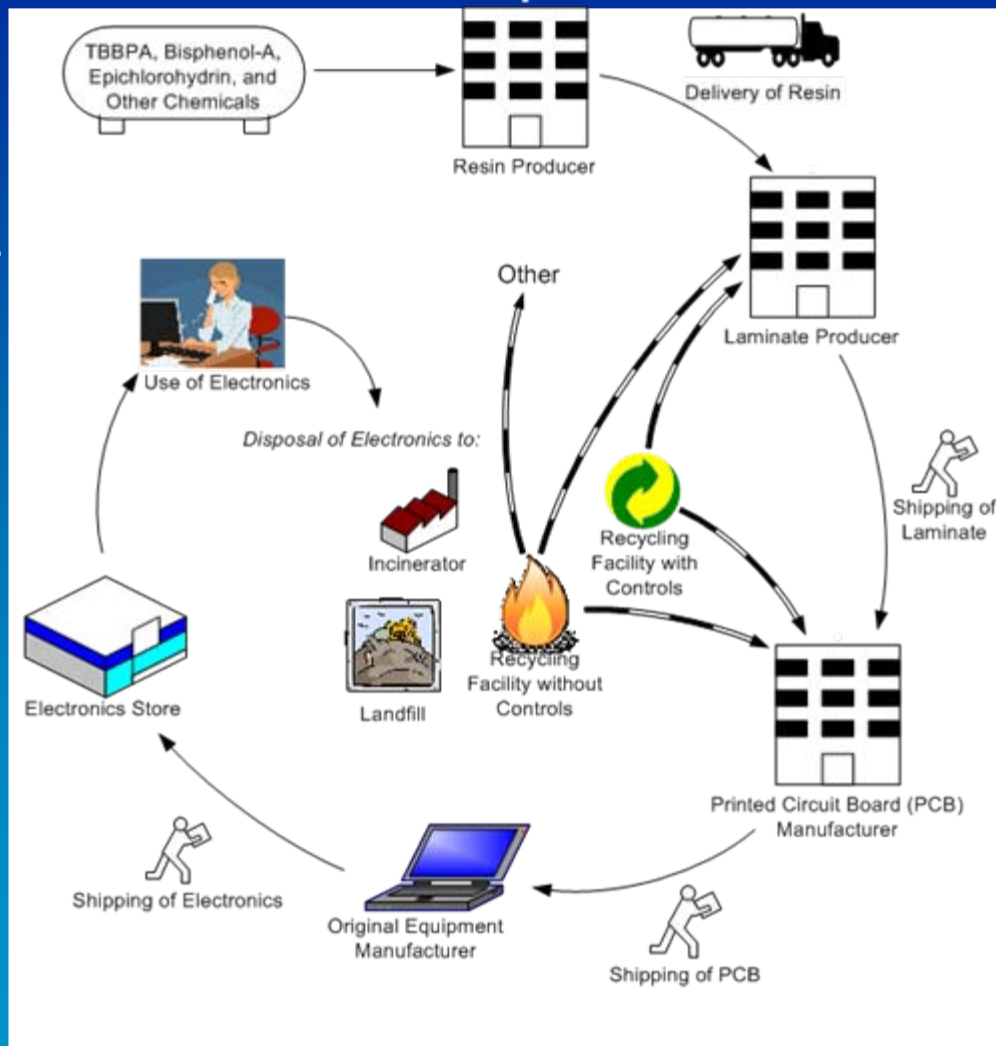
- DfE Alternatives Assessments
 - Furniture Flame Retardancy Partnership
 - Flame Retardants in Printed Circuit Boards
 - Lead-Free Solder in Electronics
 - Wire & Cable
- DfE Formulator Program
 - Recognizing Safer Formulations
 - Safer Detergents Stewardship Initiative
- DfE Auto Refinishing Best Practices



Flame Retardants in Printed Circuit Boards Partnership

Purpose:

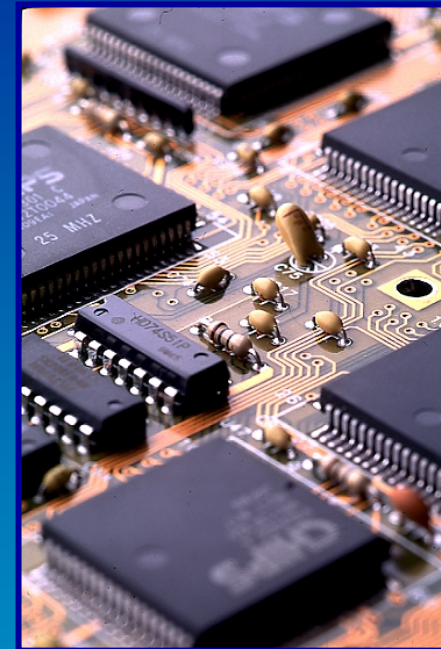
Evaluate flame retardants
for FR-4 laminate materials
in printed circuit boards



Flame Retardants in Printed Circuit Boards Partnership Drivers



- Highest volume brominated flame retardant used in printed circuit boards - at approx. 330 million pounds/year (Tetrabromobisphenol A / TBBPA)
- Industry need for information on flame retardants
- Concern by some stakeholders over environmental impacts and combustion by-products



Flame Retardants in Printed Circuit Boards Partners



Flame Retardant Manufacturers

- Albemarle
- Chemtura
- Ciba
- **Clariant**
- ICL Industries
- Supresta
- Nabaltec
- Trade Associations: BSEF, HFFREC

Electronics Suppliers

- Resin manufacturers
- Laminators
 - Park Electrochemical
 - Endicott
 - Nan Ya
 - Matsushita Electric Works
 - Hitachi
 - ITEQ
 - Isola
- PCB manufacturers
- Trade Associations: IPC – Association Connecting Electronics Industries

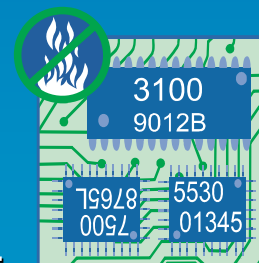
Electronics Manufacturers

- Dell
- Fujitsu Siemens
- Hewlett Packard
- IBM
- Intel
- Lenovo
- Panasonic/Matsushita
- Sony
- Trade Associations: iNEMI, ITIC, NEMA, HDPUg

Environmental Groups

- Clean Production Action
- **GreenBlue**
- Greenpeace

Universities



Flame Retardants in Printed Circuit Boards

Goal and Scope



- Goal: To identify and characterize commercially available flame retardants and their environmental, health, safety and environmental fate aspects in FR-4 printed circuit boards.
- Apply life-cycle thinking to consider hazards and exposures.
- Use EPA New Chemicals Program criteria to evaluate hazard and environmental fate concerns

Flame Retardants in Printed Circuit Boards

- Laminate Materials
 - Nan Ya
 - MEW
 - ITEQ
 - Isola
 - TUC
 - Supresta Laminate
- Flame Retardants
 - TBBPA (tetrabromobisphenol A)
 - DOPO
 - Fyrolflex PMP
 - Aluminum hydroxide
 - Exolit OP 930
 - Melapur 200
 - Silicon dioxide
- Performance considerations
 - iNEMI – Testing electrical and mechanical properties
 - HDPUG – Compiling existing information in a database

Flame Retardants in Printed Circuit Boards Assessment Methodology - Hazard



- Detailed hazard reviews
 - Based on publicly available literature
 - Determine whether endpoints can adequately be characterized based on OECD guidelines
 - Measured confidential data from EPA and chemical companies
 - Estimations from EPA New Chemicals Program
 - Professional judgment of EPA staff
- Summary of EPA assessment for environmental and human health endpoints
 - High, Medium, Low

Flame Retardants in Printed Circuit Boards

Presentation of Hazard Information



Human Health Hazard Concern Ecotoxicity Hazard Concern Environmental Hazard Concern

Company	Chemical	% in Formulation ^s	Human Health Effects							Ecotoxicity		Environmental	
			Cancer Hazard	Skin Sensitizer	Reproductive	Developmental	Neurological	Systemic	Genotoxicity	Acute	Chronic	Persistence	Bioaccumulation
Albemarle	SAYTEX RZ-243												
	Proprietary E Tetrabromophthalate diol diester		L	L	L*	L*	L	M*	L	L	H	L ^Δ	L
	Proprietary B Aryl phosphate		L	L	M*	M*	M	M*	L	H	H	L	M
	Triphenyl Phosphate CAS # 115-86-6		L	L	L	L	L	M	L	H	H	L	L
Ameribrom	FR513												
	Tribromoneopentyl Alcohol CAS # 36483-57-5		M	L	M	M	M	M	M	M	M	L	L
Great Lakes	Firemaster 550												

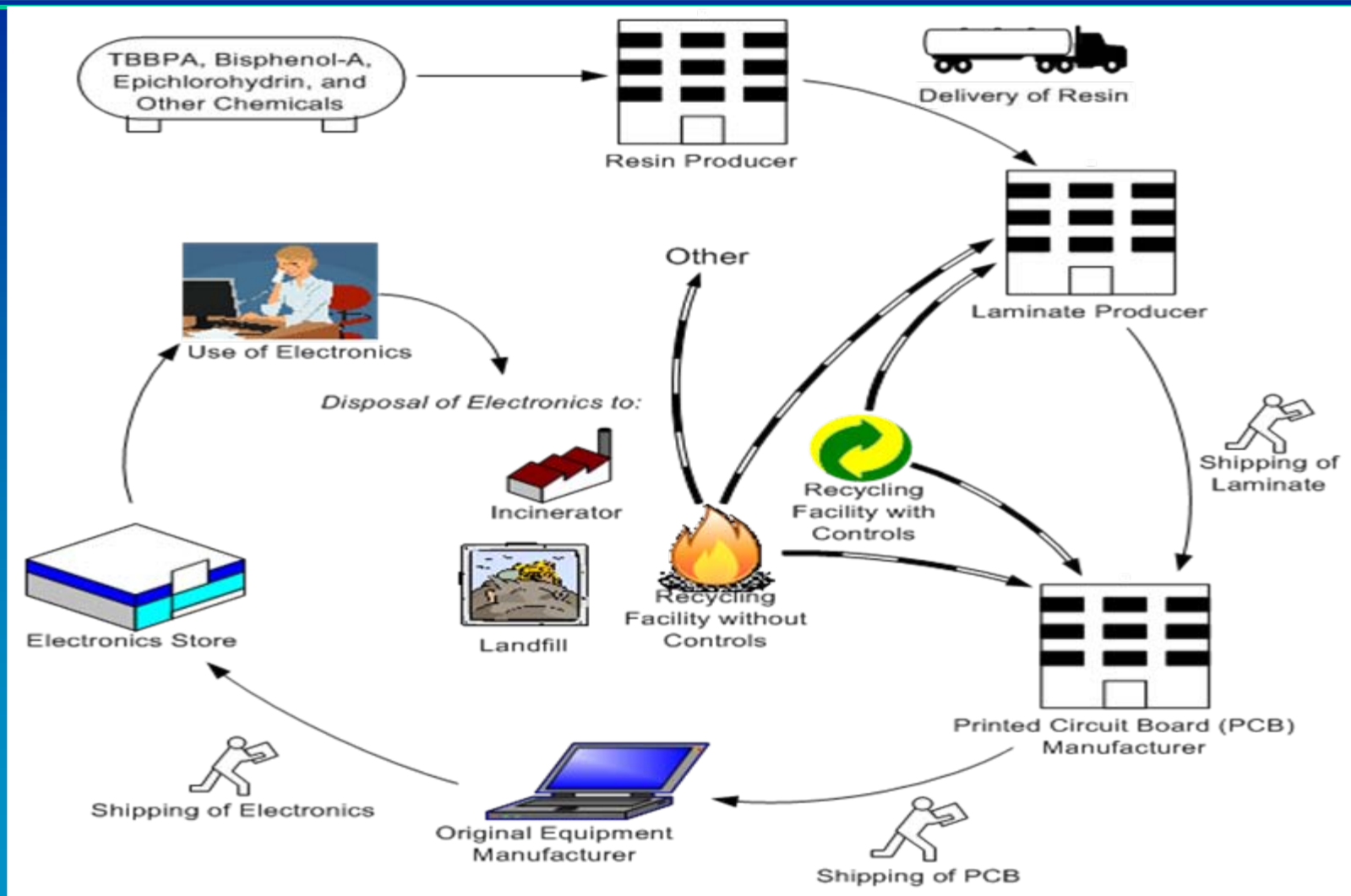
■ Example based on Furniture Flame Retardants Report

Flame Retardants in Printed Circuit Boards Exposure Considerations



- Risk = Hazard * Exposure
- Need to consider opportunity for exposure
 - Ability to persist and bioaccumulate
 - Physical/Chemical Properties
 - Water Solubility
 - Vapor Pressure
 - Physical State
 - Dispersibility
 - Use of Best Practices
 - Reactive vs. Additive Chemicals

Flame Retardants in Printed Circuit Boards Exposure Considerations



Flame Retardants in Printed Circuit Boards Combustion Testing



- Electronics Waste Concerns
 - Potential for formation of hazardous thermal degradation products (combustion testing, offgassing)
 - Potential for leaching
- Scenarios discussed and considered
 - Open burning
 - Smelting
 - Incineration
 - Offgassing – testing needs identified
 - Landfill – existing methods not appropriate

Flame Retardants in Printed Circuit Boards Combustion Testing



- Information Needed
 - Goal: Compare the combustion byproducts from FR-4 laminates and printed circuit board (PCB) materials with different flame retardants during potential thermal end-of-life processes, including open burning, incineration, and smelting.
 - Testing will be a first step in providing industry with a comparative analysis of combustion byproducts from these materials
 - Information will help inform further studies to better understand these byproducts in real-world scenarios
- Challenges
 - Reproduction of scenarios
 - Measuring unknown by-products
 - Small sample sizes

Flame Retardants in Printed Circuit Boards Combustion Testing Approach



- Developed proposal in consultation with EPA Office of Research and Development and University of Dayton Research Institute
- Methods
 - Quartz Tube Reactor
 - Cone Calorimeter
 - XRF Analysis and GC/MS
 - Characterize samples
 - Analyze for CO, CO₂, O₂, halogenated dioxins and furans, polyaromatic hydrocarbons, organics, heavy metals, bromine, acid gases, etc...

Flame Retardants in Printed Circuit Boards Combustion Testing



- Phase One
 - Materials include: phosphorous-based laminate, TBBPA-based laminate, laminate with no flame retardant
 - Conditions include: Reactor Temp at 300, 700, and 900C, with and without oxygen
 - Replicates will indicate variability
- Phase Two
 - Materials include: five additional laminate materials, populated circuit boards
 - Conditions based on phase one
 - Replicates based on phase one

Flame Retardants in Printed Circuit Boards Combustion Testing



- **Sponsors**

- Boliden
- Supresta
- ITEQ
- HP
- Clariant
- Ciba Specialty Chemicals
- Sony
- Intel
- Isola
- Dell
- Fujitsu-Siemens
- BSEF
- Matsushita
- Nabaltec
- IBM

- **Lead Researchers**

- Richard Striebich, University of Dayton Research Institute
- Brian Gullet, EPA Office of Research and Development

- **In-kind Contributors**

- Isola
- Nan Ya
- Matsushita
- ITEQ

Flame Retardants in Printed Circuit Boards Status



- Stakeholders from the electronics industry, printed circuit board supply chain, chemical manufacturers, environmental NGOs, and academia continue to guide the partnership
- Evaluated ecological and human health hazards and environmental fate of flame retardant chemicals
- Finalized funding for industry-sponsored combustion testing
- Preparing samples for combustion testing of laminate materials
- Preparing draft report (excluding test results) for public comment
– February 2008

Flame Retardants in Electronics Waste

- Important to consider the big picture
- Design is one way to help address electronics waste concerns
- Electronics circuit materials continually evolving
- Need better understanding of synergies among chemicals and materials
- Sharing information and international opportunities



Thank You!

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